10/575135
IAP20 Rec'd PCT/PTO 06 APR 2006
[10191/4605]

METHOD FOR REGULATING THE STATE OF CHARGE OF AN ENERGY ACCUMULATOR IN A VEHICLE HAVING A HYBRID DRIVE UNIT

The present invention relates to a method for regulating the state of charge of an energy accumulator for storing electrical energy in a vehicle having a hybrid drive unit, a motor vehicle in particular, as well as a vehicle having the features cited in the preambles of Claims 1 and 8.

Background Information

Motor vehicles having a hybrid drive unit have, in addition to an internal combustion engine, at least one electrical machine which is able to be coupled to the power train of the motor vehicle. During generator operation, this electrical machine provides electrical energy which is stored in an energy accumulator, formed by the vehicle battery, until it is supplied to a consumer of the motor vehicle. During motor operation, the electrical machine alone or together with the internal combustion engine is used for the propulsion of the motor vehicle, in the latter case it being used to absorb the fluctuations in the output power of the power train, so that as far as possible the internal combustion engine is always kept in a consumption-optimized operating range in order to increase the efficiency of the drive and to reduce the environmental impact due to pollutants of the internal combustion engine. In order to ensure that sufficient energy is available to supply the electrical machine and the other consumers of the motor vehicle, the state of charge of the vehicle battery is continuously monitored and, as a rule, kept at a predefined constant value. In the event of a drop in the state of charge below this value, a charge controller of the battery requests electrical energy from the electrical machine which thereupon goes into generator operation in order to recharge the battery. However, this battery recharge is unnecessary when the motor vehicle is decelerated shortly thereafter and substantial amounts of kinetic energy of the motor vehicle are converted into electrical energy by the electrical machine and fed into the battery. While the vehicle is decelerating, the entire kinetic energy of the motor vehicle usually cannot be recovered; as a rule, however, a substantial portion can.

Advantages of the Invention

The method according to the present invention having the features cited in Claim 1 and the vehicle according to the present invention having the features cited in Claim 8 have the advantage over the related art that the kinetic energy of the vehicle may be taken into account in charging the energy accumulator in order to avoid the energy accumulator being charged by conversion of part of the driving power of the internal combustion engine if it is to be expected or it is likely that shortly thereafter a substantial amount of electrical energy is fed anyway into the energy accumulator due to deceleration of the vehicle.

The method according to the present invention for charge regulation is usable in particular in motor vehicles having a hybrid drive unit whose energy accumulator is operable with a variable state of charge, such as the newly developed NiMH (nickel metal hydride) battery. Using the method according to the present invention in these motor vehicles, the amount of energy stored in the energy accumulator may be kept variable; energy may be saved by predefining a suitable setpoint value, making it possible to lower the fuel consumption and reduce the environmental impact.

According to a preferred embodiment of the present invention, charging of the energy accumulator is delayed as the vehicle's velocity increases, preferably by lowering a setpoint value of the state of charge as the vehicle's velocity increases in such a way that, due to energy removal from the energy accumulator, the actual value of the state of charge drops below the setpoint value only at a later point in time.

Since it is normally not possible to recover the entire kinetic energy during deceleration of the vehicle, another preferred embodiment of the present invention provides that the setpoint value of the state of charge is lowered as a function of the instantaneous velocity by a value which corresponds to a likely charge to be received by the energy accumulator during deceleration of the vehicle from this instantaneous velocity to a standstill.

The setpoint value is appropriately predefined by a characteristic curve which is dependent on the velocity of the vehicle, a relatively simple regulation being possible when the setpoint value of the state of charge is lowered proportionally to the velocity of the motor vehicle. However, since the kinetic energy of the vehicle increases with the square of the velocity and thus, during deceleration by a certain velocity difference, the likely amount of electrical energy increases superproportionally with the velocity, the setpoint value of the state of

charge may also be lowered in such a way that it superproportionally decreases with increasing velocity.

According to another advantageous embodiment of the present invention, the setpoint value is not lowered when energy for charging the energy accumulator is generated because of other reasons, for example, via energy recovery during a downhill drive. It is appropriate in this case to store the possibly generated surplus energy in the energy accumulator independently from the velocity in order to use it for its charge.

The velocity-dependent setpoint value of the state of charge may not only be used for the charge regulation of the energy accumulator, but may additionally also be included in an operating strategy for the internal combustion engine and the electrical machine.

Drawing

The present invention is subsequently explained in greater detail in an exemplary embodiment based on the drawing.

Figure 1	shows a possible schematic diagram of components of a hybrid drive of a motor vehicle according to the present invention;
Figure 2	shows a possible characteristic curve of the setpoint value of the state of charge of a battery of the motor vehicle as a function of the vehicle's velocity;
Figure 3	shows another possible characteristic curve of the setpoint value of the state of charge of the motor vehicle battery.

Description of the Exemplary Embodiment

The hybrid drive unit of a motor vehicle schematically represented in Figure 1 includes in a known manner an internal combustion engine 10 and an electrical machine 12. Internal combustion engine 10 is coupled to an output shaft 20 which drives drive wheels 18 of the motor vehicle via a clutch 14 and a transmission 16. Electrical machine 12 is also coupled to transmission 16 in order to keep internal combustion engine 10 always in a consumption-optimized operating state so that electrical machine 12 is able to supply part of the mechanical energy required for the propulsion of the motor vehicle. Furthermore, electrical

machine 12 is used for generating electrical energy for supplying other consumers of the motor vehicle and may additionally be used as the starter for the internal combustion engine and/or as the sole drive for the motor vehicle at a relatively low velocity. Furthermore, the motor vehicle includes in a known manner a tachometer 22 which determines the instantaneous velocity of the motor vehicle from the instantaneous speed of drive wheels 18 or output shaft 20 and conveys it to an onboard computer 24.

Electrical machine 12, which is regulated by a control unit 26, is fed in its motor operation by a battery 28 of the motor vehicle, used as an energy accumulator, and recharges the battery in its generator operation when the instantaneous state of charge of battery 28 falls below a predefined setpoint value. Battery 28 is of a type which is able to be operated with a variable state of charge, such as an NiMH battery for example. An inverter 30 including a current regulator, which is situated between the battery and electrical machine 12 and the charge controller in control unit 26, which determines the instantaneous state of charge of battery 28 and sets it to the predefined setpoint value, are used for regulating the state of charge of battery 28.

If the motor vehicle is not being decelerated, electrical machine 12 is driven in this operating state by internal combustion engine 10 via transmission 16 and converts part of the mechanical power generated by the internal combustion engine into electrical energy which is then fed into battery 28. In order to keep the fuel consumption caused by this as low as possible, not only the instantaneous state of charge of the battery is taken into account in a conventional manner in the regulation of the charge of battery 28, but also the instantaneous velocity of the motor vehicle in such a way that a velocity-dependent setpoint value is used instead of a constant setpoint value of the state of charge, the velocity-dependent setpoint value being lowered with increasing velocity, at least within certain limits.

By using this type of regulation, the instantaneous kinetic energy of the motor vehicle may be taken into account; it is in part converted into electrical energy which in turn may be utilized for charging battery 28 when the motor vehicle is decelerated the next time. Since such a deceleration generally takes place within not too long a time span, a complete charge of battery 28 may be delayed up to this point in time due to the velocity-dependent lowering of the setpoint value of the state of charge. Since the complete charge of battery 28 takes place with the aid of the kinetic energy recovered during braking instead of using part of the

driving power of internal combustion engine 10, energy and thus fuel may be saved and the environmental impact may be reduced.

The velocity-dependent setpoint value of the state of charge is predefined by charge controller 26 which contains a microcomputer, for example, which calculates the setpoint value by taking into account the instantaneous velocity v_{actual}, which is transmitted from onboard computer 24 and is generally available in digital form on a vehicle bus, and a setpoint characteristic curve which is dependent on the velocity and is stored in the microcomputer.

Two such setpoint characteristic curves dependent on the velocity are represented in Figures 2 and 3 by way of example. While in the characteristic curve shown in Figure 2, plotted over velocity v, the setpoint value of state of charge ($SOC_{setpoint}$) drops linearly in a predefined velocity range between standstill (v_0) and an upper limit (v_1) and is then kept constant in order to not fall below a lower limit of state of charge SOC_{min} required by battery 28 and for the cold start, it remains constant in the characteristic curve shown in Figure 3 up to a predefined minimum velocity v_{min} and drops subsequently up to maximum velocity v_{max} with increasing slope, remaining, however, above limit SOC_{min}.

In both characteristic curves, the difference between the respective velocity-dependent setpoint value $SOC_{setpoint}(v)$ and a constant conventional setpoint value $SOC_{setpoint}k$, indicated in the diagram by dashed lines, corresponds to that portion of the kinetic energy which may be recovered during deceleration from instantaneous velocity v_{actual} to a standstill and which may be fed into battery 28 in the form of electrical energy. If battery 28 is not charged during deceleration of the motor vehicle for any reason, charging takes place as a rule directly subsequently using the driving power of internal combustion engine 10.

Using the described method, a rough prediction of the future energy flow may be established and unnecessary charging of battery 28 may be avoided in many cases. However, because of the latter reason, charging of battery 28 should not be dispensed with in the case of every energy oversupply, even when $SOC \geq SOC_{setpoint}$.

The state of charge regulation according to the present invention is particularly usable in motor vehicles; it may, however, also be used in locomotives having hybrid drive units. The method according to the present invention is generally suitable for all hybrid vehicle concepts, such as those which have another electrical machine in addition to electrical

machine 12. Moreover, the method according to the present invention may not only be used as a stand-alone but also in combination with other methods for state of charge regulation.